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Lead Exposure in Young Children from Dust and Soil in the United Kingdom

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A survey of metals in United Kingdom dusts and soils has confirmed widespread lead contamination with a geometric mean value for lead in surface (0-5 cm) garden soils of 266 μg/g and in housedusts of 561 μg/g (excluding old mining areas). A subsequent detailed survey of 97 householders in Birmingham with 2-year-old children showed dust lead loading in the home environment to be an important predictor of blood lead concentrations in young children, when both variables fell within the normal range for the U.K. The total estimated lead uptake by the young child was 36 μg/day of which 1 μg was by inhalation and 35 μg by ingestion.

Introduction

An extensive survey of lead in garden soils and household dusts undertaken in England, Scotland, and Wales within the period November 1981 to June 1982 confirmed the presence of elevated concentrations both within and around a significant percentage of homes (*1,2*). Concentrations were highest in older homes and in London. On a national basis, around 10% of floordusts sampled exceeded 2000 μg/g lead, thus confirming the conclusions of the U.K. Royal Commission on Environmental Pollution (RCEP) (*3*) and others that ingestion of dust by hand-to-mouth activity could in many cases constitute a significant and important route of lead exposure in the young child. Over the period November 1984 to February 1985, a comprehensive study was undertaken in the inner city area of Birmingham, Britain's second largest city, in an attempt to quantify lead intake from dust in relation to other sources of lead intake by the 2-year-old child (*4*).

This paper summarizes the results of the national survey and subsequent detailed study in Birmingham and reviews the results in terms of the aims and objectives of this conference.

Survey of Lead in Soil and Dusts

A national survey was commissioned by the United Kingdom Department of the Environment and sampling carried out from November 1981 to June 1982 in 53 locations in England, Scotland, and Wales. The majority of sites were selected to reflect a variety of geographical locations, the overall distribution of the population, and a range of industrial/urban development. Seven London boroughs were sampled, and some areas of historical mining, including a group of villages in the "geochemical hotspot" of Derbyshire, were sampled.

The sampling and analytical protocols have been described in detail elsewhere (*1,2,5*). One hundred houses were sampled in each of the locations. Samples from each home comprised a bulk sample of housedust from the householder's vacuum cleaner and a surface garden soil (0–5 cm), being a composite of 25 subsamples collected from exposed surfaces. The following were also sampled in each location: *a*) playground dusts from 5 schools (composite of 25 subsamples from each); *b*) roadside dusts taken from the gutter from 10 roads (composite of 25 subsamples); *c*) vegetable garden soils from 5 houses (composite of 25 subsamples, 0–15 cm depth); *d*) surface soils (0–5 cm) from 5 parks (composite of 25 subsamples). Soils (2-mm fraction ground in a Tema mill) were digested in concentrated nitric acid and dusts (1-mm fraction) in a mixture of 4:1 concentrated nitric and perchloric acids prior to analysis by flame atomic absorption spectrophotometry, with rigorous quality control (*6*).

The results are summarized in Figure 1 and further subdivided in Table 1. Concentrations of lead ranged widely in all the media sampled, with a geometric mean value for lead in surface (0–5 cm) garden soils of 266 μg/g and in housedusts of 561 μg/g (national value including London but excluding old mining areas). In London the corresponding values were 654 μg/g for soils and 1010 μg/g for dusts, which probably reflected the city's long history of industrialization and urban development coupled with the large population and traffic density. The largest concentrations of lead occurred in old mining villages in Derbyshire, with a mean concentration in soil of 5610 μg/g and in housedust 1870 μg/g lead. It is of interest that in locations other than Derbyshire, concentrations of lead in housedusts on average exceeded those in soils by a factor of 2, reflecting internal sources such as paint. In Derbyshire the opposite was found, with lead in soil three times greater than that in housedust. In this geochemical hotspot, the heavily contaminated external

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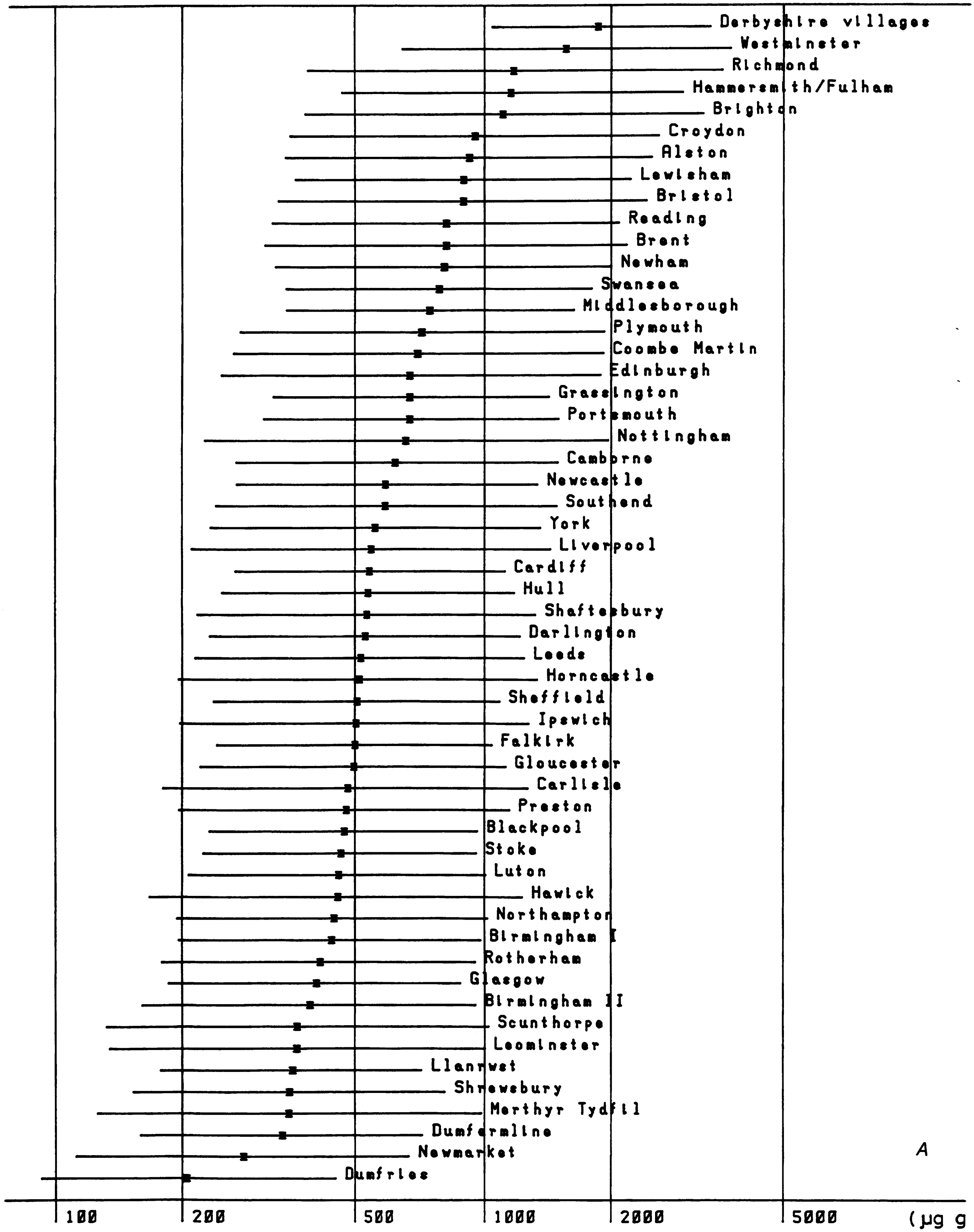

FIGURE 1. Concentrations of lead in (*A*) housedust and (*B*) garden soil for the locations sampled in the National Survey of the U.K. Each bar shows the geometric mean ± 1 SD (i.e., 68% range) for 100 houses. *Continued on next page.*

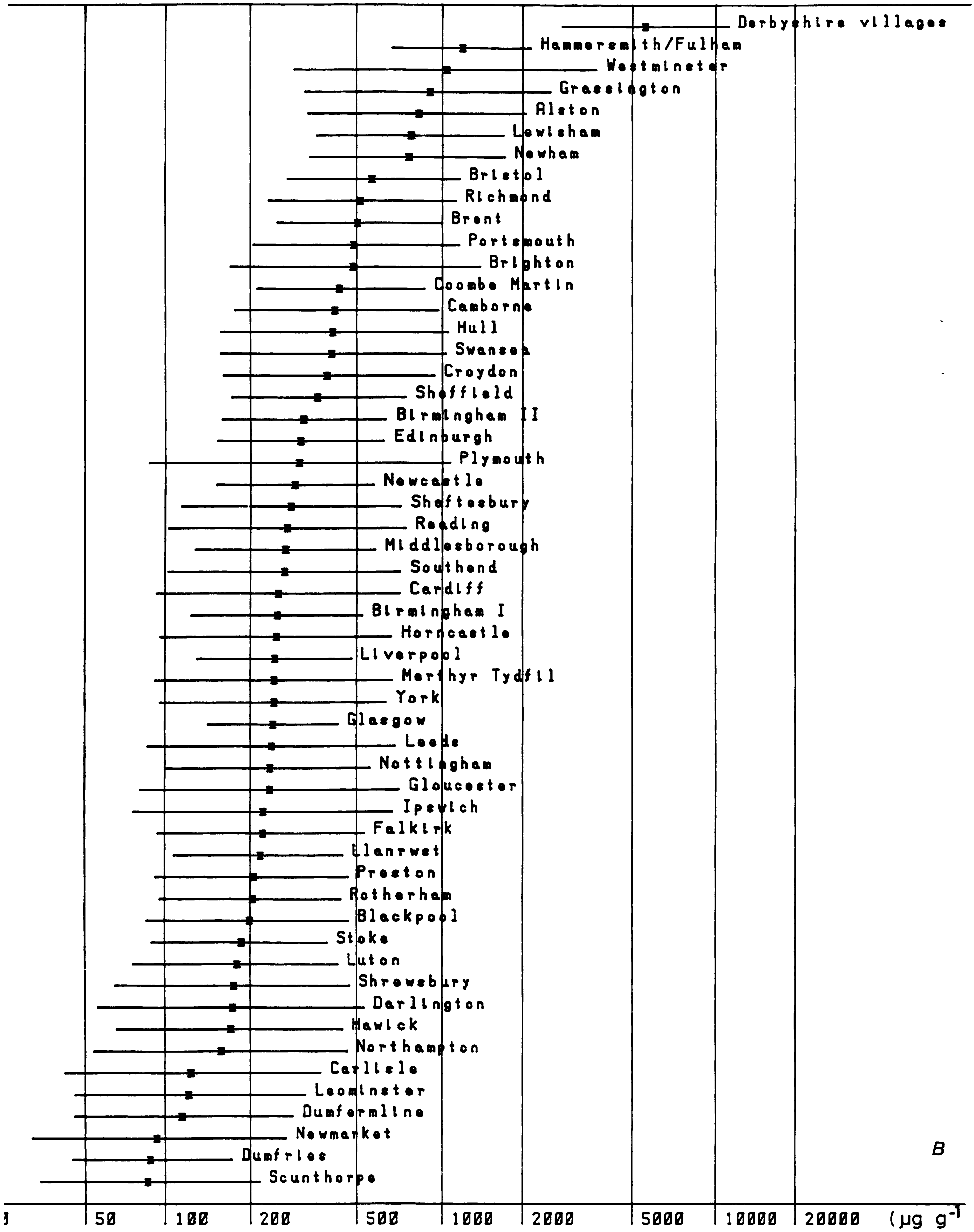

FIGURE 1. *Continued.*

Table 1. Lead concentrations in survey locations derived according to sample type (μg/g).

Sample type	All study locations less hotspots	London boroughs	Derbyshire mining villages	Remaining geochemical hotspots
Housedust				
n	4,638	683	100	492
Geometric mean	561	1,010	1,870	631
Range	5–36,900	5–36,900	606–7,020	74–40,300
Road dust				
n	400	65	9	38
Geometric mean	786	1,354	2,160	564
Range	45–9,660	172–9,660	1,190–4,620	176–3,180
Playground dust				
n	220	34	5	18
Geometric mean	289	430	4,390	400
Range	11–6,860	93–6,860	1,190–13,400	53–21,700
Garden soil				
n	4,126	578	89	433
Geometric mean	266	654	5610	493
Range	13–14,100	60–13,700	1,180–22,100	49–8,340
Vegetable plot soil				
n	193	29	5	25
Geometric mean	270	571	8,730	454
Range	24–2,560	137–2,560	1,140–26,500	90–3,250
Public garden soil				
n	221	35	5	22
Geometric mean	185	294	3,030	348
Range	20–1,820	28–1,260	2,140–4,920	98–8,510

environment would seem to act as a source of lead (soil particles, discrete mineral grains, etc.) to internal dusts.

Housedusts exceeded 2000 μg/g lead in 10% of the homes overall, in 18% of the London homes and in 44% in Derbyshire. Ninety-three percent of the garden soils exceeded 2000 μg/g lead in Derbyshire. Analysis of the data showed a highly significant relationship between the concentration of lead in the housedust and that in the garden soil ($r = 0.531$, $p = 0.001$, $n = 4512$). However, this relationship may be influenced by the fact that lead in dust and soil increased with house age; this was confirmed in later more detailed studies in York (*7*) and in Brighton (*8*). Results from the latter study are shown in Table 2. This national survey clearly confirmed that lead contamination is widespread in both soils and dusts in Britain and established an urgent need to assess the relative importance of lead-rich dust and soil as a source of lead exposure to the young child (*2*).

Table 2. Geometric mean lead concentrations in housedusts and surface garden soils (0–5 cm) in and around houses of various age in Brighton.[a]

House age	*n*	Lead concentration, μg/g: Housedust	Soil
Pre-1870	20	982	1146
1870–1919	38	1874	1014
1920–1939	31	619	368
1940–1959	22	433	292
1960–1986	28	241	131

[a]Adapted from Davies and Thornton (*8*).

Study of Lead Intake by Two-Year-Old Children in Birmingham

A comprehensive investigation was designed to provide quantitative information for lead intakes by two-year-old urban children in inner-city Birmingham. This collaborative program involved the Applied Geochemistry Research Group, Imperial College (environmental sampling and analysis, and development of lead exposure model); Environment, Health and Behaviour Research Group, University of Birmingham (behavioral studies); Trace Element Unit, University of Southampton (blood lead analysis); Food Science Division, Ministry of Agriculture, Fisheries and Food (MAFF) (dietary study); and Central Directorate of Environmental Protection, Department of the Environment (coordination and overall interpretation).

This study was carried out within the inner ring-road and to the east of the city center of Birmingham and was based on the homes of 97 two-year-old children. These children were chosen from 183 randomly selected children who had been born in, and were still resident in, central Birmingham and who were then aged 24 ± 2 months. A stratified subset of 106 children was selected of which 97 completed the study. Sampling and analytical protocols have been described elsewhere (*4,9,10*). At each house the following samples were taken:

a) housedust samples from i) the householder's own vacuum cleaner and ii) the child's bedroom and main playroom using an adapted Electrolux 350 vacuum cleaner
b) pavement and road dust (composite of 25 subsamples) taken immediately outside the house
c) surface soil (0–5 cm) from exposed surfaces (composite of 25 subsamples)
d) air from three locations: the child's bedroom, main playroom, and immediately outside the house
e) handwipes daily for 7 consecutive days using "All-Fresh" wet wipes (Beecham's Health Care, St. Helens, England)
f) food and water (a duplicate diet study was organized by MAFF over a 7-day period in each home)
g) venous blood samples were taken at the beginning of the study and a second sample from 56 children some 5 months later.

Behavioral measurements were made using a portable video recorder filming each child for approximately 4 hr. A detailed household questionnaire consisting of 140 items covered family and social background together with the physical environment of the home. Results are summarized in Table 3.

Both concentration and loading of lead in dust ranged widely, with geometric mean values of 424 μg/g and 60 μg/m², respectively. The geometric mean blood lead concentration, 11.7 μg/100 mL (5th and 95th percentiles 6 and 24 μg/100 mL, $n = 97$), was similar to that found previously using children of this age in central Birmingham (*11*). Agreement between repeat samples was very good ($r = 0.82$).

The correlation of blood lead concentrations with average indoor air lead concentrations was virtually zero. As with the results for handwipes, the correlation of blood lead concentrations with lead loading in housedust ($r = 0.46$) was

Table 3. Lead in blood, environmental samples, handwipes, diet, and water.

Sample	Units	n	Geometric mean	Percentiles 5th	95th
Blood	µg/100 mL	97	11.7	6	24
Air					
Playroom	µg/m^3	607	0.27	0.08	0.88
Bedroom	µg/m^3	599	0.26	0.09	0.81
External	µg/m^3	605	0.43	0.12	1.53
Dust	µg/g	94	424	138	2093
Soil	µg/g	87	313	92	1160
Dust loading	µg/m^2	93	60	4	486
Handwipes	µg	704	5.7	1.9	15.1
Diet (food and beverages)	µg/week	96	161	82	389
Water	µg/L	96	19	5	100

much higher than with the lead concentrations (r = 0.21). In addition, the correlation of blood lead with the dust lead loading was higher than with the handwipe lead (r = 0.34). The correlations with soil lead concentrations (r = 0.18) was similar to that with dust lead concentrations. Although the correlations of blood lead with both dietary lead concentration and intake were very small (and not statistically significant), that with water lead concentration (r = 0.39) was similar to the correlation with dust lead loading.

The relative importance of the various sources of lead was assessed using multiple linear regression, and a lead exposure model was developed for the study children. The best regression model (R^2 = 35%) relating blood lead to the various sources of lead was:

$$\log \text{PbB} (\mu g/100mL) = 0.55 + 0.10 \log xi + 0.14 \log \text{PbW} (\mu g/L) + 0.07S$$

where PbB = blood lead concentration; PbW = water lead concentration; xi = dust lead loading multiplied by the rate for hands touching all objects (including the floor); and S = a dichotomous variable taking the value 1 or 0 depending upon whether or not either of the child's parents smoked cigarettes.

The addition of air lead concentration, soil lead concentration, or dietary lead intake (or any combination) gave non-significant regression coefficients for the variables concerned and only marginal improvements in the R^2 values. It would appear, therefore, that in a typical inner-city area of the U.K., the amount of dust lead present in the home environment is an important predictor of blood lead concentration in young children. It should be stressed that this was the case even though the dust lead levels present in the study homes were well within the normal range reported previously for homes throughout the U.K.

An assessment of the relative importance of the different sources of lead, based on assumptions used by the U.K. Royal Commission on Environmental Pollution (*3*), indicates that lead uptake from inhalation would be only just over 1 µg/day and assuming that lead from dust and from the diet are equally bioavailable, uptake by ingestion 35 µg/day. The resulting total estimated uptake (36 µg/day) is only about one-third of that calculated by the RCEP, but the proportions of 3% from inhalation and 97% from ingestion are similar (*12*). However, given the uncertainties surrounding the figures for dust ingestion and absorption by the gut, both the estimated proportions and the total amounts of lead from dust and from the diet must be treated with caution.

Discussion

Data from the national survey of metals in urban dust and soils have shown an appreciable proportion of households to be contaminated with lead. In London, for example, the geometric mean concentration of lead in housedust exceeds 1000 µg/g and over England, Scotland, and Wales as a whole exceeds 500 µg/g lead. At present there is no statutory limit for lead in dusts in Britain, though the Greater London Council suggested a guideline figure of 500 µg/g lead (in the 0.5-mm fraction of external dusts) as justifying investigation and 5000 µg/g justifying some element of control (*13*). Trigger concentrations for lead in soil in Britain have recently been proposed for sites about to be developed, but these are not applicable to sites already in use (*14*). The subject of setting trigger concentrations has recently been reviewed by Morgan and Simms (*15*), who state "each contaminant and for each end-use, a minimum of two values are required: a lower or 'threshold' value below which a site may be treated as uncontaminated for that purpose, and an upper or 'action' value at which the site cannot be used for that purpose until remedial action is taken." Tentative threshold trigger concentrations for lead in soil of 500 µg/g for household gardens and 2000 µg/g for amenity land have been proposed, although action concentrations have yet to be specified (*14*).

The Birmingham study has for the first time shown a significant relationship between levels of environmental lead within the home (lead concentration in floordust and lead loading in floordust) and blood lead in the 2-year-old child. Children's blood lead increases in response to increasing lead loading within the home in a typical inner-city situation where blood lead rarely exceeds 25 µg/100 mL and dust lead concentrations fall within a normal range. If the action limit value for blood lead of 25 µg/100 mL were to be lowered to say 15 µg/100 mL, this relationship would have considerable implications, and many British households would require either some form of remedial action or advice on cleaning procedures.

It is difficult to make comparisons between lead exposure from indoor dust and from exposed surfaces of soil. In the latter case, the concern would be lead concentrations and area exposed rather than with lead loading. Much information is required before it will be possible to assess the importance of the wide range of chemical and physical soil characteristics that may influence the bioavailability of lead as a controlling factor in human exposure. In Britain, the 2-year-old child spends more time at play indoors than outdoors and in terms of future guidelines, a focus on indoor dusts would seem more appropriate than on soil. However, the geochemical hotspot is a special case and will need careful appraisal.

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